Journal of Forestry Research (2014) 25(1): 163−170
DOI 10.1007/s11676-014-0442-5

ORIGINAL PAPER

Effects of harvesting on productivity of bay leaf tree (*Cinnamomum tamala* Nees & Eberm): Case from Udayapur district of Nepal

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Received: 2012-02-02; Accepted: 2013-01-23

Abstract: Cultivation of bay leaves (*Cinnamomum tamala* Nees & Eberm**)** to fulfil household income needs is a long established practice in Udayapur district of Nepal. The practices adopted by farmers for bay leaf harvesting have not, however, been validated by scientific investigation for their sustainability. To investigate the impacts of harvesting on the yield of branch, leaves and biomass of leaves, a two-year research project was conducted in farm fields at Kopche village of Routa VDC in Udayapur district, Nepal. Four different harvesting treatments, the orientation and the order of branches were taken as independent variables to test their effects on number of branches, leaves and biomass of leaves. Orientation, harvesting treatments and order of branches had a significant effect on the number of branches, but not on the number of leaves or biomass (fresh and dry weight) of leaves in the year of harvest. Between two consecutive harvests there was no significant difference in the number of branches, leaves or biomass. Lower two-thirds portion of the trees produced the largest number of leaves and branches of the fourth order in both years. Therefore, lower two-thirds portion of the trees were suitable for harvesting. Our findings support farmer experience that no change in productivity of leaves is observed when harvesting each year. For long term sustainability, harvesting should be conducted without debarking of trees or damage to branches. Our findings could be extrapolated to and tested in other areas with different access and user rights where the rotation for harvest is fixed or regulated without research evidence.

Keywords: agro forestry, tree leaf harvesting, yield, management practices, sustainable development

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Introduction

Non timber forest products (NTFPs) attract increasing attention from development planners and environmentalists because NTFPs serve multiple functions and can contribution to improved livelihoods of rural and marginalized communities. But certain Himalayan NTFP species or groups of species are degraded through overuse and knowledge associated with them is declining (Dhar et al. 2002; Karki 2004; Aumeeruddy-Thomas 2005; Subrat 2005). Continued harvesting will deplete the resource, although some species are better able to sustain continuous off-take than others e.g., in the case of plants, those exhibiting abundant and frequent regeneration and rapid growth (Cunningham and Mbenkum 1993). Effective methods are needed to assess NTFPs and monitor impacts of harvesting to ensure that the desired development and conservation objectives can be met. Several studies have been conducted on the impact of harvesting of different types of NTFPs and sustainable harvesting limits have been estimated (O'Brien and Kinnaird 1996; Nantel et al. 1996; Ticktin et al. 2002; Endress et al. 2004; Siebert 2004). These studies highlight the consequences of harvesting NTFPs and roles of local communities in their sustainable management. Sustainability refers not only to production but also to ecological sustainability, which has wider connotations for ecosystem management (Blanco et al. 2005; Bi et al. 2007).

Cinnamomum tamala Nees and Eberm is called bay leaf tree or Indian Cassia in English and tejpat in Nepal. A member of the family Lauraceae, it is a tree of moderate size that attains a height of 8 m, and a girth of 150 cm. It is an evergreen tree and is also cultivated. The leaves are commonly called bay leaves. The genus *Cinnamomum* is represented by 350 species worldwide. Its natural habitat is the tropical and sub-tropical Himalayas from 900 to 2,500 m ASL. It is also found in tropical and sub-tropical Asia, Australia, the Pacific region and South Asia (Parajuli 1998). In Nepal it is cultivated in Udayapur and Palpa districts

(Lamichhane and Karna 2009) and grows wild in Central, Eastern and Western Nepal, especially in Udayapur, Palpa, Rasuwa, Sindhuli, Dolpa, Rukum and Jajarkot (Parajuli 1998). Ayurveda describes the use of leaves of tejpatra in the treatment of ailments such as anorexia, bladder disorders, dryness of mouth, coryza, diarrhea, nausea and spermatorhea (Dighe et al. 2005). The leaf is an important ingredient in the spice industry and the essential oil of the leaves, known as *Tejpat* oil, is medicinally used as a carminative, antiflatulent, and in perfumes, toothpastes, and industrial fragrances. Antibacterial, antifungal and strong antitermitic activities are reported by Dighe et al. (2005). Its bark is used as a substitute for *Cinnamomum zeylenicum* which is native to Sri Lanka and India (Jakhetia et al. 2010). The collection of bay leaf in forest and farmlands to fulfil household income needs is a long established tradition in Nepal (Parajuli 1998).

In Nepal, people collect the bay leaf from both community and government forests. Large-scale cultivation is reported from Udayapur district (Lamichhane and Karna 2009). The average number of trees per household was reported as 72, ranging from 10 to 155 trees. Since bay leaf is an evergreen tree, farmers can collect its leaves throughout the year but the main harvesting season is from October to December. The small branches are broken with the leaves and dried in the shade for 3–4 days. The leafy branches are then bundled for the market. Parajuli (1998) reported the annual average yield per tree was 13 kg of dry leaves; however, Lamichhane and Karna (2009) reported that quantity depends upon local factors and a tree can yield from 8–20 kg of dry leaves in a year.

Leaf quality is better in the winter, while bark collection is effective in the pre-monsoon and post monsoon seasons when the tree is still active. Farmers usually avoid collecting both leaves and bark during the monsoon because of problem of drying of leaves and bark, and also because this is the busy season for rice growing (Lamichhane and Karna 2009). Interviews conducted in Udayapur district of Nepal indicated that collecting bay leaf and bark in years of high yield can provide more income, than can be earned working as temporary field labor (Sita Rana Magar, pers. comm., Bay Leaf Farmer, Routa VDC, Udayapur, December 29, 2010).

Lamichhane and Karna (2009) documented the harvesting practices of bay leaves in cultivated plots in Udayapur district of Nepal. Markets for bay leaves, as for other species of NTFPs, play an important role in the way people harvest them. Trader preference for quantity over quality is an important factor leading to indiscriminate harvesting (Bhatarai and Croucher 1996).

Farmers also tend to over-harvest because this earns more income and because the market prices are low (Karki 2005). Destructive methods of harvesting can lead to decreased productivity and regeneration, and even tree mortality (O'Brien and Kinnaird 1996; Nantel et al. 1996; Ticktin et al. 2002; Endress et al. 2004; Siebert 2004). Scientific research on the sustainability of harvesting bay leaves is not reported. Such studies are, therefore, necessary to estimate sustainable harvest levels and to provide a reference for the assessment of harvest impacts (Jong and Utama 1998).

Farmers in Udayapur harvest bay leaves every year from all accessible parts of the tree (Lamichhane and Karna 2009). Their experience does not suggest a reduction in yield of leaves. Their practices were not, however, scientifically validated for sustainability or for long-term economic benefits. The objective of this research trial was to investigate the effects of harvesting on the yield of branches, leaves and biomass of leaves when subjected to differential harvest treatments to understand the productivity of leaves and needs for improved management.

Materials and methods

To ascertain whether the harvest of bay leaves from cultivated plots is ecologically and economically sustainable, we conducted a harvest trial in cultivated plots at 1,300–1500 m a.s.l. in Kopche village of Routa VDC in Udayapur District. Four harvest treatments, four orientations and the order of branches were taken as independent variables to test their influence on numbers of branches and leaves, and on biomass of leaves.

To measure the numbers and emergence of new shoots and leaves, and to estimate the biomass harvested from trees of similar ages, a total of four harvest treatments were designed:

Harvest practice 1 (H1): Harvesting only the lower one-third of the tree and leaving the upper two-thirds (mid and top portions) unharvested.

Harvest practice 2 (H2): Harvesting only the lower two-thirds of the tree and leaving the upper one-third unharvested.

Harvest practice 3 (H3): Harvesting only the upper one-third of the tree and leaving the lower two-thirds unharvested.

Harvest practice 4 (H4): A control with no harvest.

To administer the treatments, a cultivated plot belonging to a farm household in Kopche village was selected. The entire plot of land was divided into five blocks. In each block five bay leaf trees about 10 years in age were randomly selected, for each of the four treatments. Each tree was divided into three parts, *viz.*, lower one-third, lower two-thirds and upper one-third from the crown and divided into four compass orientations East (E), West (W), North (N) and South (S). The height of the bole from ground level to the bottom of the crown was measured. The diameter of the trees at breast height (1.37 m above ground level) was recorded for each tree.

Under each harvest treatment the numbers of branches and sub-branches were counted, means were calculated, and branches and sub-branches were coded up to the fourth sub branch in each orientation for the whole tree. Each block included five replications of each treatment. For all branches and each orientation in harvested trees, two branches were selected and the numbers of leaves were recorded for each branch following the order up to the fourth order branch. The fresh and dry weight of the leaves was recorded. The same sampling was repeated in all five blocks after one year (before 2nd harvest) and data were recorded. Observations on the different vegetation and land use features were recorded to explain and substantiate the different tree behavioral patterns.

The following three levels of hypothesis (H_o) were developed

to test the influence of the harvesting patterns on branches, leaves and biomass. The factor properties for branches are shown in Table 1 and those for leaves and biomass are shown in Table 2.

Table 1. Factor properties for branches

Factor name	Type	Level	L1	L2	L3	L4	L5
Orientation	Qualitative	4	East	West	North	South	
Treatment	Qualitative	3	L1/3	L 2/3	U 1/3		
Branch Order	Qualitative	5	5	4	3	2	1

L: Level

Hypotheses for branch

H_{01}: There is no influence of orientation of branches on the number of branches.

H_{02}: There is no influence of the harvest treatment on the number of branches.

H_{03}: There is no influence of branch order on the number of branches.

Hypotheses for leaves and biomass

H_{01}: There is no influence of orientation of branches on the number of leaves and biomass.

H_{02}: There is no influence of the harvesting treatments on the number of leaves and biomass.

H_{03}: There is no influence of the order of branches on the number of leaves and biomass.

Table 2. Factor properties for leaves and biomass

Factor name	Type	L	L1	L 2	L 3	L 4	L5	L6	L7	L 8
Orientation	Qualitative	4	East	West	North	South				
Treatment	Qualitative	3	L 1/3	L 2/3	U 1/3					
Category of branch	Qualitative	8	1	2	3	4	5	6	7	8

L: Level

Data were recorded in specially designed formats and coded and analyzed with SPSS version 16. Factorial analysis was conducted to estimate the interaction of three factors, *viz*., orientation, treatment and category of branches (order of branches) on the number of branches, leaves and biomass (fresh weight and dry weight). The mean number of branches, leaves and biomass of the leaves were recorded in two successive years.

Results

Branches

In terms of treatment, the maximum number of branches was in the lower two-thirds harvest in the first year. This was followed by the lower one-third and upper one-third respectively. In the second year after the harvest treatments the maximum number of branches was in the lower two-thirds part, as in year 1. This was followed by the lower one-third and upper one-third, respectively, also as in year 1 (Table 3).

Table 3. Number of branches by treatment

Treatment	Mean	N	Std. deviation	Maximum
Lower 1/3 harvest Yr 1	102.91	97	201.55	1124.00
Lower 1/3 harvest Yr 2	90.45	97	148.34	697.00
Lower 2/3 harvest Yr 1	114.53	100	222.45	1375.00
Lower 2/3 harvest Yr 2	141.34	100	244.78	1631.00
Upper 1/3 harvest Yr 1	52.00	100	86.28	417.00
Upper 1/3 harvest Yr 2	58.03	100	85.94	342.00

In terms of orientation, the maximum number of branches was recorded in the south quadrant, with 35% of total branches. Fewest branches were recorded in the west quadrant. In the second year and after treatment, the maximum number of branches was in the west quadrant, with 26.8% of the branches. The least number of branches was in the north (Table 4).

Table 4. Number of branches by orientation

Orientation	Mean	N	Std. deviation	Maximum
East Yr 1	94.02	74	193.26	1044.00
East Yr 2	98.4	74	180.35	969.00
West Yr 1	68.0	74	134.04	810.00
West Yr 2	103.82	74	236.5	1631.00
North Yr 1	69.6216	74	109.83	537.00
North Yr 2	82.1892	74	116.6	538.00
South Yr 1	126.56	75	251.2	1375.00
South Yr 2	102.17	75	149.6	624.00

Yr: year

In terms of the category of branches, 65% of the branches were second order. Fewest branches were of the fifth order. In the second year, the maximum number of branches was again recorded for second order branches. The fifth order had the least number of branches (Table 5).

The ANOVA of the general full factorial design for the first year of observations showed significant effect of the model (f=3.55; p <0.001). Individually, the main effects of the factors were significant (f=18.20; p <0.001), which leads us to reject the null hypotheses. The results indicate that orientation, treatments and order of branches had a significant effect on the number of branches. However, for the combination of two factors, *viz.*, treatment and orientation, orientation and category of branch, and category of branch and treatment were not significant (f=1.41; p >0.05). The three way interactions between category of branch, orientation and treatment were also not significant (f=0.3867; p >0.05).

The ANOVA of the general full factorial design for the second

year of data also showed a significant difference in the model (f=3.24; p <0.001). Individually the main effects of the factors were also significant (f=15.93; p <0.001), again leading us to reject the null hypotheses for the number of branches in the second year. However, two way (f=1.31; p >0.05) and three way (f=0.56; p >0.05) interactions were not significant.

Overall no difference in the number of branches was observed between two years (T test; p >0.05). The results indicate that the harvest treatments did not have any significant influence on the production of branches by bay leaf trees.

Table 5. Number of branches by branch order

Category of branch	Mean	N	Std. deviation	Maximum
B5 Yr 1	1.78	60	0.97	5.00
B5 Yr 2	1.90	60	0.96	5.00
B4 Yr 1	25.46	60	22.82	113.00
B4 Yr 2	30.45	60	32.86	216.00
B3 Yr 1	72.33	60	62.4	296.00
B3 Yr 2	1.20	60	219.75	1631.00
B2 Yr 1	2.88	60	286.75	1375.00
B2 Yr 2	2.67	60	228.34	969.00
B1 Yr 1	58.56	57	162.78	1124.00
B1 Yr 2	61.82	57	93.65	318.00

B1, B2, B3, B4 and B5 represent the descending order of the branches. Yr: year

Leaves

In terms of treatments in year 1, the maximum number of leaves (41%) was found in the lower two-third harvest followed by the lower one-third harvest (34.2%) and the upper one-third harvest (24.7%). In the second year the number of leaves was again greatest on the lower two-thirds of the tree, with an increment of around 4% compared to the previous year. Leaves on both the lower one-third and upper one-third of the trees decreased in the second year (Table 6).

In years 1 and 2, the maximum number of leaves was recorded in the southern orientation (Table 7).

About 73% of the leaves were recorded on fourth order branches, followed by 26% on third order branches in year 1. In year 2, fourth order branches also had the maximum number of leaves (Table 8).

The ANOVA of the general full factorial design for year 1 showed no significant difference in the model (f=0.93; p >0.05). Individually the main effects of the factors were also not significant (f=0.74; p >0.05), leading us to accept the null hypothesis that orientation, harvest treatment and branch order had no significant effect on the number of leaves. Also combinations of two factors, *viz.*, treatment and orientation, orientation and branch order, and branch order and treatment were not significant (f=1.11; p >0.05). The three way interaction between category of branch, orientation and treatment was also not significant (f=0.82; p >0.05).

Table 6. Number of leaves by treatment

Treatment	Mean	N	Std. deviation	Maximum
Lower 1/3 rd harvest Yr 1	573.20	160	1112.81	6309.00
Lower 1/3 rd harvest Yr 2	5.56	160	1093.07	6231.00
Lower 2/3rd harvest Yr 1	686.96	160	1266.16	7535.00
Lower 2/3rd harvest Yr 2	8.1261	160	1344.25	7530.00
Upper 1/3rd harvest Yr 1	413.89	160	825.54	5685.00
Upper 1/3rd harvest Yr 2	4.2369	160	805.37	5490.00

Yr: year.

Table 7. Number of leaves by orientation

Orientation of branch	Mean	N	Std. deviation	Maximum
East Yr 1	631.86	120	1135.82	6328.00
East Yr 2	671.28	120	1188.29	7466.00
West Yr 1	481.23	120	955.80	5121.00
West Yr 2	525.40	120	1010.48	4825.00
North Yr 1	451.32	120	855.69	4014.00
North Yr 2	494.45	120	872.62	4350.00
South Yr 1	667.66	120	1336.78	7535.00
South Yr 2	699.85	120	1325.11	7530.00

Table 8. Category of branches and leaves

Category of branches	Mean	N	Std. deviation	Maximum
S1B1 Yr 1	0.0000	60	0.00	0.00
S1B1 Yr 2	0.6333	60	3.45	21.00
S1B2 Yr 1	6.1167	60	23.45	110.00
S1B2 Yr 2	83.4667	60	121.75	422.00
S1B3 Yr 1	6.2215	60	685.74	2926.00
S1B3 Yr 2	8.2692	60	948.56	4350.00
S1B4 Yr 1	1.7595	60	1610.99	6328.00
S1B4 Yr 2	1.8077	60	1662.47	7466.00
S2B1 Yr 1	0.0000	60	0.00	0.00
S2B1 Yr 2	0.0000	60	0.00	0.00
S2B2 Yr 1	0.0000	60	0.00	0.00
S2B2 Yr 2	30.3000	60	75.60	316.00
S3B3 Yr 1	572.73	60	648.1	2803.00
S3B3 Yr 2	582.45	60	558.81	2221.00
S2B4 Yr 1	1503.6	60	1571.20	7535.00
S2B4 Yr 2	1450.5	60	1564.86	7530.00

*B1, B2, B3 and B4 represent the ascending order of the branches. S1 and S2 represent the branch number. Yr: year.

In year 2, the ANOVA of the general full factorial design showed no significant difference in the model (f=0.821; p >0.05). Individually the main effects of the factors were also not significant (f=0.580; p >0.05), leading us to accept the null hypothesis for the effect of the three factors on the number of leaves. Also for combinations of two factors, *viz.*, treatment and orientation, orientation and branch order, and branch order and treatment were not significant (f=1.33; p >0.05). The three way interaction between branch order, orientation and treatment was also not significant (f=0.584; p >0.05).

Overall, in response to the treatments, no significant difference

was observed in the production of leaves between years 1 and 2 (T test; $p > 0.05$).

Biomass

Fresh weight of leaves

In terms of the treatments, the mean fresh weight of leaves for the lower one-third harvest was 262 g in year 1. For the lower two-thirds and upper one-third the mean fresh weights of leaves were 323 and 184 g, respectively. In terms of orientation, the maximum fresh weight of the leaves was recorded in the south quadrant (305 g) followed by the east (298 g). The mean fresh weights in the west and north quadrants were 217 and 210 g, respectively. In terms of branch order, the maximum fresh weight of the leaves was recorded on fourth order branches followed by third order branches.

In year 2, in terms of treatment, the mean maximum fresh weight of leaves was 383 g for the lower two-third harvest. The mean fresh weights of the leaves for the lower one-third and upper one-third were 256 and 197 g respectively. In terms of orientation the maximum fresh weight of the leaves was recorded in the south (323 g) followed by the east (309 g). The mean fresh weight in the west and north was 251 and 231 g, respectively. In terms of branch order, the maximum fresh weight of leaves was recorded on fourth order branches, followed by third order branches.

The ANOVA of the general full factorial design for year 1 showed no significant difference in the model (f=0.9704; $p > 0.05$). Individually, the main effects of the factors were also not significant (f=1.181; $p > 0.05$), leading us to accept the null hypothesis for the effect of the three factors on the fresh weight of leaves. Also for combinations of two factors, *viz.*, treatment and orientation, orientation and branch order, and branch order and treatment, were not significant (f=0.991; $p > 0.05$). The three way interaction between branch order, orientation, and treatment were also not significant (f=0.89; $p > 0.05$).

In year 2, there was no significant difference in the model (f=0.82; $p > 0.05$). Individually, the main effects of the factors (f=0.82; $p > 0.05$), the two-way interaction (f=0.65; $p > 0.05$) and three-way interactions (f=0.98; $p > 0.05$) were also not significant, leading us to accept the null hypothesis for the effect of the three factors on the fresh weight of leaves.

Dry weight of leaves

In terms of the treatments, the mean dry weight of leaves for the lower one-third harvest was 160 g in year 1. For the lower two-thirds and upper one-third the mean dry weights of leaves were 132 and 89 g, respectively. In terms of orientation, the maximum dry weight of leaves was recorded in the south (105 g) followed by east (144 g). The mean dry weights in the west and north were 106 and 102 g, respectively. In terms of branch order, the maximum dry weight of leaves was recorded on fourth order branches, followed by third order branches.

In year 2, in terms of the treatments, the maximum mean dry weight of leaves was 187 g for the lower two-thirds harvest. For the lower one-third and upper one-third the mean dry weights of leaves were 127 and 97 g, respectively. In terms of orientation, the maximum dry weight of leaves was in the south (157 g) followed by 152 g in the east. The mean dry weights in the west and north were 124 and 114 g, respectively. In terms of branch order, the maximum dry weight of leaves was found on fourth order branches followed by third order branches.

The ANOVA of the general full factorial design for year 1 showed no significant difference in the model (f=1.09; $p > 0.05$). Individually, the main effects of the factors were not significant (f=0.79; $p > 0.05$). The three way interaction was not significant (f=0.87; $p > 0.05$), but the two way interactions were significant (f=1.42; $p < 0.05$). We reject the hypotheses but accept two way interactions between treatment and branch order, branch order and orientation, and treatment and orientation as influences on the dry weight of leaves. However, we accept the null hypothesis regarding the one and three way interactions as the results are not significant at p=0.05.

In year 2, there was no significant difference in the model (f=0.78; $p > 0.05$). Individually, the main effects of the factors were also not significant (f=1.00; $p > 0.05$). The two-way interaction (f=0.72; $p > 0.05$) and three way interaction (f=0.78; $p > 0.05$) were also not significant. We accept the null hypothesis for the effect of the three factors, one way, two-way and three-way interaction as not significant for the dry weight of leaves.

The difference in the influence of the factors between years may be attributed to the harvest treatments. No significant difference in the biomass (fresh and dry weight of leaves) was observed between the two years (T test; $p > 0.05$). From the overall study results it is thus clear that the treatments do not influence the emergence of branches, leaves and biomass of leaves.

Discussion

Propagation and domestication of NTFPs are not only important to increase farm incomes but also to ease the exploitation pressure on natural forests due to the over-exploitation of NTFPs, which is caused by expansion in national and regional demand and globalization in the use of natural products for health care as well as by the food and cosmetic industries. Between 50%–100% of households in the northern part of central Nepal and about 25%–50% in the middle part of the same region are involved in collecting NTFPs for sale, the materials being traded to wholesale markets in India. The income received represents 15%–30% of the total income of poorer households (Olsen 1997). Considering the economic potential and dwindling natural populations of *C. tamala* in several forest ranges of India, the species has been recommended for *in situ* as well as *ex situ* conservation by several authors (Sharma et al. 2009). The promotion and monitoring of local experimentation in management techniques, through participatory research with harvesters, may be one of the most important keys to identifying harvest practices that promote persistence (Ticktin 2004).

In terms of orientation, the maximum number of branches (35%) was recorded in the south, followed by 26% in the east, 19.3% in the north and 18.9% in the west. In year 2, the maxi-

mum number of branches was recorded in the west and was 0.1% higher than in the south. The number of branches in the southern orientation declined from 35% in first year to 26.7% in second year. Number of branches in the east increased by 1% and in the north decreased by 3%. These minor changes in numbers of branches by orientation may be attributed to root and shoot coordination. The enlargement of aerial parts is accompanied by increased demands for water, minerals, and mechanical support that are met by coordinated growth of the root system. Several factors apparently are concerned with control, because shoot and root affect each other reciprocally (Encyclopedia Britannica, www.uv.es/EBRIT/main/eb.htm).

In terms of treatments, the lower two-thirds of the tree had the maximum number of branches, followed by the lower one-third for second order branches. In year 2, the maximum number of branches were second order but in the lower two-thirds harvest. The reasons could also be due to the increased availability of light as a result of harvesting of the upper one-third, thereby stimulating the remaining leaves to higher rates of photosynthesis (Bhatt et al. 1995; Tord 2013). A bud in the main stem of a tree is influenced by the confluent auxins produced by all apices and vigorous leaves above it (in the case of the upper one-third harvests) in both the lateral branches and the stem. The differential bud burst pattern of different parts of the tree in the stems, as found in this study seems, due to this altered auxin flux along the stem (Zeng 2001).

There are four to five orders of branching patterns in bay leaf trees with maximum number of branches occurring in the second and first orders. The highest number of branches was recorded in for second order branches, comprising of 65% of all branches. After treatments in year 2 there was slight decline in the number of second order branches. Third order branches showed an increase from 16.3% in first year to 25.1% in the second year. This may be attributed to the harvesting treatments and the translocation of nutrients in the branches. Ecophysiological studies have shown that some species can allocate resources to growth and reproduction after defoliation through reallocation of stored reserves (Whitham et al. 1991). Auxins (growth hormones) in the terminal bud flow downwards and causes both the current year and previous year's dormant lateral buds to flush and lateral branches grow vigorously (Zeng 2001). Fourth order branches then emerge from the third order branch. Removal of leaves and whole shoots, as in the treatments, stimulates the development of dormant buds into shoots and increases branching (Bhatt et al. 1995). Bay leaf tree is characterized by weak apical control. It displays many branches with a rounded crown. A tree with weak apical dominance is not able to completely suppress the growth of the current year lateral buds, so, it flushes (Zeng 2001). The increased number of branches in bay trees could be attributed to this characteristic.

Between the years the maximum number of leaves was observed in the southern orientation. This may be attributed to site characteristics, harvesting patterns and the orientation of root growth which cause the tree to grow in a particular orientation. Ticktin (2004) reported the great variability in tolerance to harvest, even among species that share similar life histories; harvest types and environments can be due, at least in part, to variation in management by people. Based on our results, we rule out the influence of orientation on numbers of leaves.

In year 1, in terms of the treatments, the maximum number of leaves (41%) was recorded in the lower two-thirds harvest followed by the lower one-third harvest at 34.2% and upper one-third harvest at 24.7%. In year 2, the number of leaves was again maximal in the lower two-thirds of the tree, with an increment of around 4% compared to year 1. The reason may be attributed to the fact that harvesting the upper one-third of the trees reduced the density of the tree canopy leading to increased penetration of sunlight. Svenning and Macia (2002) predicted that sustainable extraction of *G. macrostachys* leaves for thatch will be easier to achieve in forests where the canopy has been opened by the felling of timber or is kept open under managed conditions.

Overall, our research findings do not suggest that leaf harvest adversely affects survival or condition of bay leaf trees. Farmers harvest all the accessible leaves, in all orientations from the third and fourth order branches. Our study findings also suggest that the orientation, tree part, and branch order harvested do not influence the number of branches or leaves, or the leaf biomass. The experiences of farmers show that if the leaves are hand plucked then there are no changes in the emergence of leaves in subsequent years. However, if harvested with the traditional knife or "khukri", the subsequent emergence of leaves is reduced due to the high levels of stem wounding. Wounding may reduce leaf production. Ticktin (2004) suggested that ecophysiological studies will be an important complement to experimental harvests for assessing the potential long-term effects of different management practices. It may happen that bay leaf trees do not reduce their production of leaves, but if leaves are harvested every year, many nutrients (nitrogen, phosphorus, potassium, etc.) may be exported from the ecosystem as leaves are the tree organs that are rich in nutrients (Bi et al. 2007; Blanco et al. 2005). In the long term, if these nutrient exports are not supplemented with nutrient inputs (fertilization, deposition, and seepage, etc.), the next generation of trees will grow less vigorously due to the decline of nutrient availability.

The management options available to local people are highly dependent on systems of land tenure and governance, socio-economic status, population pressure, education, government policies, and cultural factors (Ticktin 2004). Experiences during our research show that harvesting the upper one-third leads to better tree shape and emergence of leaves. Also, we observed from the control trees that the old leaves lack lusture and shine and there is a profusion of seeds. From the market point of view, traders do not prefer bay leaves with seeds attached. This explains why farmers do not leave any tree or tree part unharvested.

Conclusion

We conclude that the harvest treatments did not significantly impact the growth of branches, emergence of leaves, or leaf

biomass. The results for the number of branches, leaves and biomass indicate that the lower two-thirds of the tree produced the largest number of leaves and branches in the fourth order in both years. Thus we conclude that the lower two-thirds of the tree are the best parts for harvesting.

Based on our study findings and current farmer practices we conclude that bay leaf trees managed as plantations in farm fields can be harvested every year with no negative impact on yield. However, harvest should be carried out without debarking trees or damaging branches. The practices followed at the research sites seem to be relevant for both leaf productivity and market needs. Our results could be extrapolated to and tested in other areas with different access and user rights where the rotation for harvest is fixed or regulated without supporting research evidence.

Acknowledgement

The corresponding author is grateful to the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal, for providing the opportunity to conduct the study. Special appreciation goes to Dr. Bishnu Hari Pandit for his guidance in field work and to colleagues at ICIMOD for their review, comments and suggestions. Gratitude is expressed to the HNB Garhwal University for academic support. The comments of two external reviewers are highly appreciated for improving the quality of the manuscript. The support from the family of Ms. Sita Rana Magar who kindly allowed us to conduct the research in their land is acknowledged.

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